Computer Aided Design of Home Medical Alert System

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119 Hitchcock Hall

College of Engineering

The Ohio State University

Columbus, Ohio 43210

By

Pei Chen Kan

80 W. Lane Ave. Apt 3N

Columbus, Ohio 43201

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Abstract

This document proposes a wireless network to improve the quality of life in the homes of the deaf population. Deaf individuals are hindered by the fact that many household appliances and safety devices depend on sound as a way to alert the user. The Sound-Alert System is a project to make a system for the deaf that allows home appliances and safety devices to work without this dependence on sound. By using TopSpice simulation, it gives us ideas of expecting waveform results from each component.

Introduction

Home appliances rely heavily on sound to send a message to the residents. Kitchen appliances, doorbells, washing and drying machines, and fire alarms all alert the user by sound. For this reason, the deaf community cannot use these devices without some type of modification. There must be another way to get the messages from the devices to a deaf resident. The solution is a wireless system composed of a base unit used to integrate these appliances to a signal and a pager that is capable of vibrating and displaying written messages based on this signal. The wireless network has two main components: the appliances themselves (with transmitters attached), and a receiver that is carried by the person. This will allow deaf individuals to be immediately aware of important information such as a fire alarm, thereby increasing their independence and quality of life. The network must consistently be able to send and receive a signal throughout a typical house. This system is basic in nature, but also very versatile, and can be applied to appliances throughout the home. There are many ways in which this system could be customized to meet the specific needs of different people.

This design will incorporate a simplified form of this idea, excluding the sensor system and just using a fire alarm signal. The process of detecting the alarm signal, sending a message to the receiving end, and alerting the user is simulated. There is a microcontroller that detects the alarm and sends a signal wirelessly to a second receiving microcontroller via the RF transceivers. This microcontroller receives this signal, and subsequently powers a vibrator and a seven segment display to alert the user of the fire alarm. The power demands are also considered in this report, and a comparator circuit and voltage regulator circuit were successfully designed and implemented on the simulation. More time would be needed to complete the initial design, but the TopSpice simulation provides a basis for the design of the wireless Sound-Alert System.

Objective

This project is originated from a senior design project to compete in Texas Instrument Contest. The integration of Sound-Alert System for this research project is to use TopSpice to have simulation results in order to analyze the output waveforms of each sub-system. By using demonstration in TopSpice, it will be helpful to build out the device and detect errors in simulation. This overall system can be broken up into four sub-systems: power systems, microcontroller, wireless system, and alert system. A block diagram for whole system is shown as Figure 1.

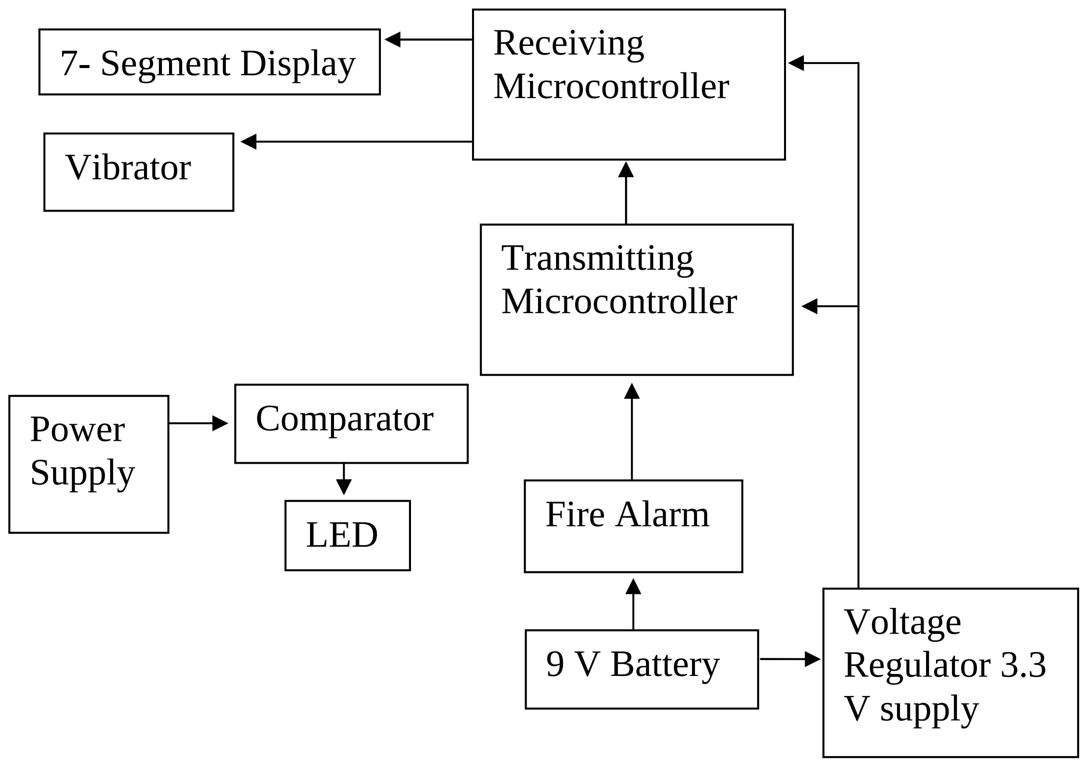

Figure 1: Overall System Block Diagram

The integration of these will allow the detection of a fire alarm signal and send the signal to the receiving end which will alert the user. Since this is a senior design project for competing in Texas Instrument Contest, most of the parts will be coming from Texas Instrument. There are four main requirements to keep in mind when designing this unit; an effective wireless system, an efficient power system, size limitations, and monetary restrictions. The wireless system needs to have low power requirements and easily work throughout an entire household. The power system needs to be long lasting. To keep the system unobtrusive a small size is ideal. The receiver will be the size of a pager or a watch so the consumer can wear it comfortably.

Detail Design

The Sound-Alert System is composed of two parts. The first is a transmitting unit placed near the fire alarm to receive a signal when the alarm goes off and send the signal to the receiving unit. The second part is a pager (receiving unit) the user carries on their person that alerts them when a fire alarm sounds. Thus, we have two units: a transmitter attachment for the fire alarm detection and a vibrating pager for the user.

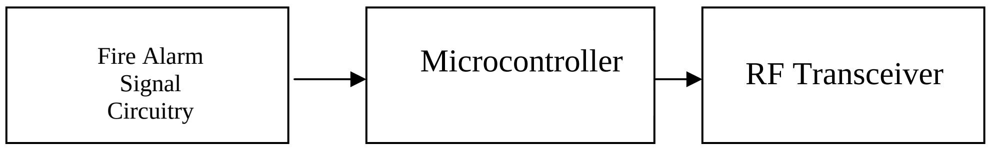

Figure 2: Block diagram representing the workflow in the transmitter unit

Figure 2 is the block diagram for fire alarm signal circuitry, microcontroller, and RF Transceiver at transmitting side.

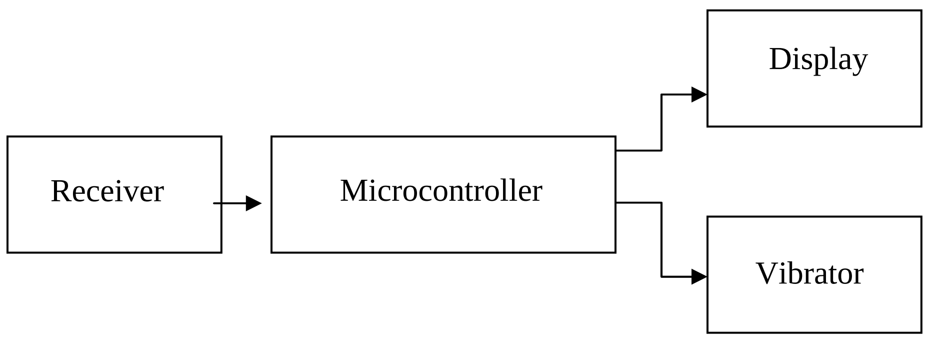

Figure 3: Block diagram representing the workflow in the receiving unit

Figure 3 is the block diagram for receiver, microcontroller, LED display, and vibrator. Both parts of transmitting and receiving units are heavily base on power system. To keep the two units small and mobile, the Sound-Alert System will be battery powered.

1. Power System

When considering a battery powered source, the most important part of the battery calculations is the current. Essentially, in terms of the power system, all the electric components are in parallel with each other, so to estimate the required current, add the supply currents of the main components and make sure to design the power system so that it is able to supply more than enough current.

Transmitter Unit: $I_{BATTERY} = I_{VREG} + I_{TRANSISTOR} + I_{RF} + I_{MICROCONTROLLER}$

Pager Unit: $I_{BATTERY} = I_{CMPR} + I_{RF} + I_{MICROCONTROLLER}$

The transmitter unit will use the 9V battery from the fire alarm itself since the transmitter unit will now be integrated with the fire alarm. The power system flow chart of transmitting unit is shown as Figure 4 below.

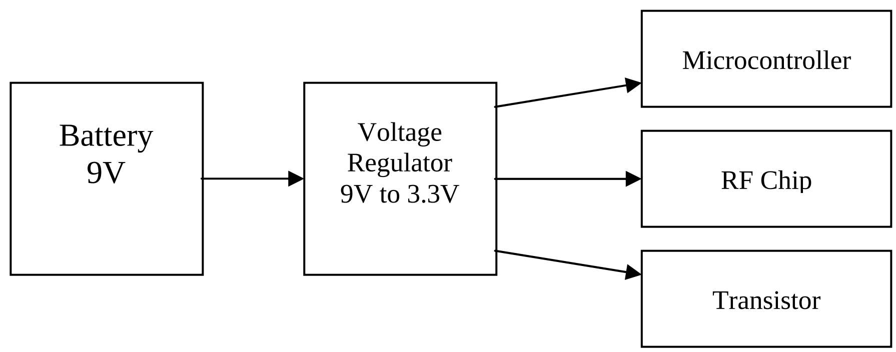

Figure 4: Transmitter Unit Power System Flow Chart

The receiver unit will still be powered by lithium ion batteries with a voltage of 3.6V. Lithium ion batteries will be chosen because they are smaller and last longer. The 3.6V value is within the acceptable input range for the microcontroller and the RF chip so it will not be adjusted. A flow chart for the receiver unit power system is shown in Figure 5.

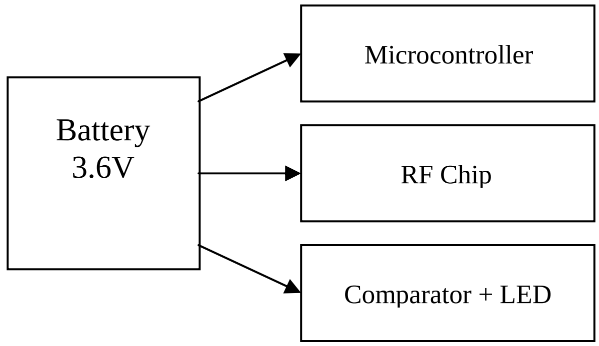

Figure 5: Receiver Unit Power System Flow Chart

TopSpice will exam if transmitting unit and receiver unit are actually power by the target voltages or not by plotting the output waveforms. There are also a comparator uses in the system by indicating low battery life of pager and voltage regulator by running the microcontrollers off of the 9V battery supply from the fire alarm.

2. Microcontroller

The system will use a low power microcontroller with many desirable properties that will aid in implementing the final design. MSP430F2012 microcontrollers used for transmitting and receiving are the main components for this system. This particular microcontroller was chosen for various reasons. It is a low power microcontroller, with many features that allow it to work with the system we will be implementing. There are fourteen digital input/output ports that will be needed to as an interface with the RF transceiver and the fire alarm. The ultra-low power can extend battery life, which will be important because the user will be wearing this pager and we will need the battery life to be long. This microcontroller is also compatible with the CC2500 RF transceivers that will be used to communicate the signal wirelessly. The target boards are very portable and size efficient for the Sound-Alert system. These microcontrollers will communicate the signal and alert the user appropriately. The structure of how the microcontrollers will be used is shown in Figure 6.

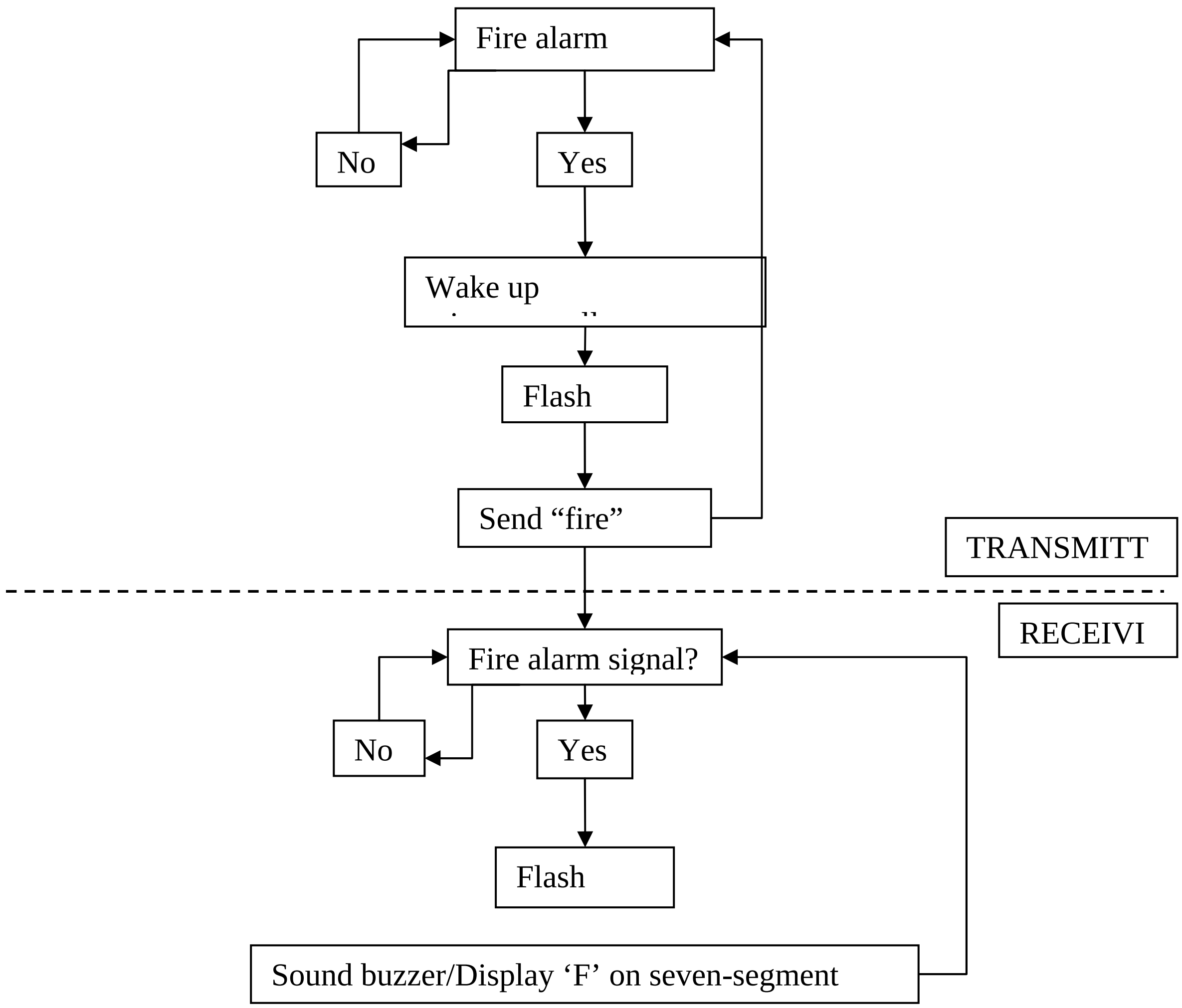

Figure 6: Flowchart of Overall Microcontroller Operations

Since microcontroller needs to send signal wirelessly to CC2500, TopSpice will be plotting the output waveform to see if microcontroller is sending and receiving the signal properly to/from CC2500 RF transceiver. There are many articles that use CAD tool to design a system then build it bases on the schematic since CAD tool already simulated out the possible output waveform or results for people to refer [1].

3. RF Transceiver

The wireless signal will be transmitted and received by CC2500 RF transceiver. On the transmitting end, the microcontroller will determine if there is an alarm, and send a signal to the CC2500. Then the CC2500 will modulate the signal. After such modulation, the CC2500 will send the positive RF output signals to the antenna for it to be transmitted to the receiver. On the receiving end, the CC2500 will be implemented into a personal pager device in receiving mode to receive the analog signals sent by the antenna. It will then send the received signals through a demodulation process to recover the original digital signals collected from the fire alarm. In addition to transmitting and receiving of the data signals, the CC2500 also consists of a digital noise isolator. Therefore, it will serve as a noise filter for the transmission of the digital signals between the two transceivers. From the CC2500 RF transceiver, TopSpice will model both transmitting and receiving sides to see the waveform before and after modulation and demodulation in order to make sure the system is working properly without noise.

4. Alert System

The alert system consists of a vibrator and 7- segment display. It is a circuit that will take the microprocessor data and use a seven-segment LED and a vibrator to inform the user of the fire alarm. First the system will receive a signal from microcontroller. Next, it will analyze the signal. Finally, it will vibrate and flash an ‘F’ on the LED to inform the user of the alarm.

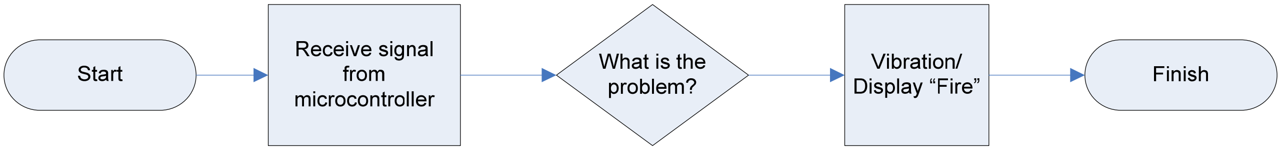

Figure 7: Flowchart for Buzzer and LED

Procedure

TopSpice will analyze the signal that is send by microcontroller to vibrator and LED to see if microcontroller is sending enough voltage for vibrator to vibrate and LED to flash. The schematic of overall system is shown in Figure 8.

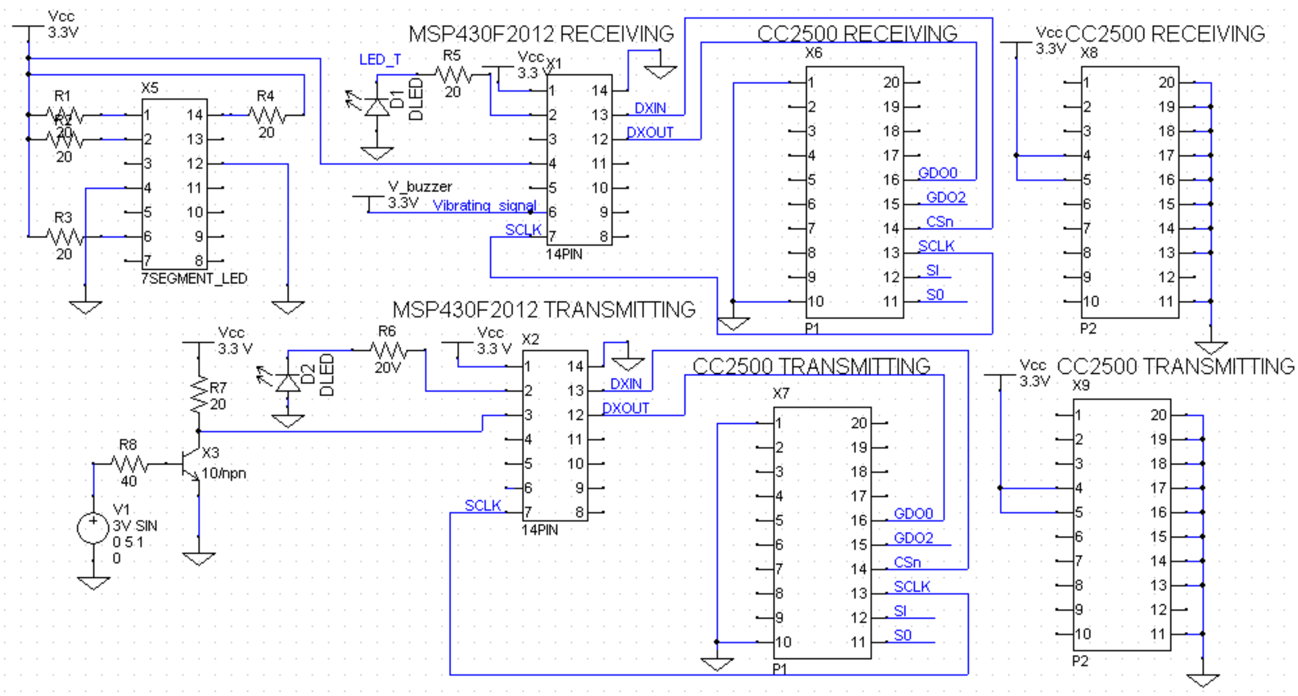

Figure 8: TopSpice Schematic for Sound-Alert System

Figure 8 has clearly shows the details of the all system. Starting from the signal intercept from fire alarm, it is V1 with the sin wave. It is connected with a npn where collector side has resistor of 20 ohms then to Vcc, base side has resistor of 40 ohms then to V1, and emitter side to ground. Between R7 and npn, it is connected to Pin 3 of MSP430F2012

Transmitting side. For MSP430F2012 Transmitting part, Pin 1 is connected to Vcc and Pin 14 to ground. Then Pin 2 is connected to a resistor of value 20 ohms then a LED flash to indicate the part is working. Pin 7, 12, and 13 of MSP430F2012 Transmitting part to CC2500 Transmitting part of Pin 13, 16, and 14, correspondingly. Another part of CC2500 Transmitting P2 has the Pin 4 and 5 to Vcc and Pin 11, 13 to 20 to be grounded.

Starting from 7 Segment LED at the left hand side, Pin 1, 2, 6, and 14 are connected with a resistor value of 20 ohms then to the voltage of 3.3V, and both Pin 4 and 12 are grounded. Then 7 Segment LED is connected to MSP430F2012 receiving side's Pin 4. Its Pin 1 is to Vcc equal 3.3V and Pin 14 to ground. For Pin 2, it is connected to a resistor value of 20 ohms then to a LED flash to indicate that MSP430F2012 receiving side is working. The buzzer is connected to Pin 6, which we simulate voltage out of it. Pin 7, 12, and 13 from MSP430F2012 receiving are connected to Pin 13, 16, and 14 on CC2500 Receiving part. CC2500 Receiving has Pin 1 and 10 to ground. CC2500 Receiving P2 part share the same pins set up as CC2500 Transmitting P2 part.

After trials and errors for the schematic in Figure 8, I could not get the proper waveforms for any of the excepted waveforms because this is a brand new project that nobody has done it by using TopSpice before. It keeps showing me that "NO CIRCUIT ELEMENTS FOUND IN NETLIST." I either separate the schematic into transmitting and receiving parts or put them all together; yet the simulations still did not turn out properly. Also, TopSpice has a SPICE netlist option that first build in the program, yet the schematic was asking for different SPICE netlist option that does not exist in the program.

1. Sub-Circuit

In order to solve blank block problem in TopSpice, we can draw a sub-circuit of the component such as X5 in Figure 8, which is 7 Segment LED. However, the details circuit inside the 7 Segment LED is not released to the public. The same thing happened to both MSP430F2012 and CC2500. The following example is to use sub-circuit to define an element. Figure 9 below that it has the sub-circuit to define each inverter and become ring oscillator.

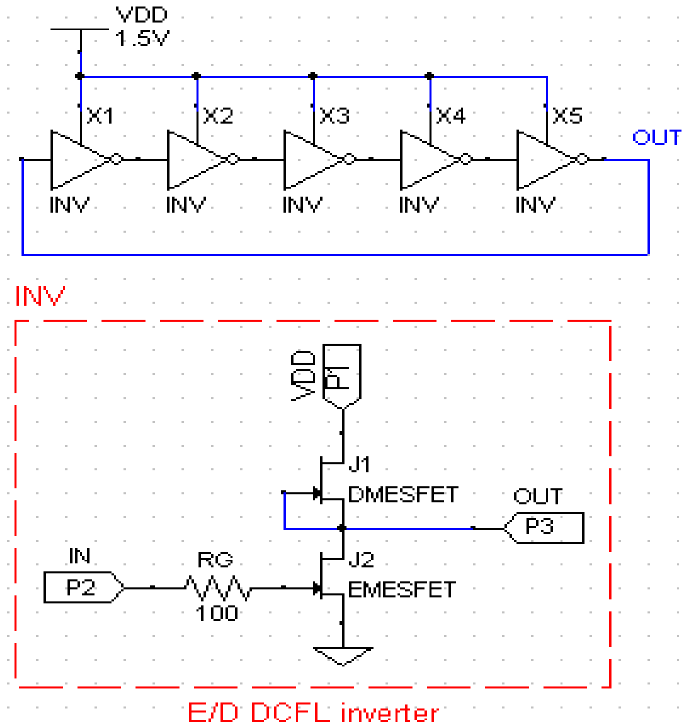

Figure 9: TopSpice Schematic of Ring Oscillator.

The circuit inside the red dot line is the sub-circuit of inverter. It defines each inverter in the upper schematic in order to let the program know the meaning of inverter. Those inverters form a ring oscillator. Figure 10 shows the transient analysis of ring oscillator.

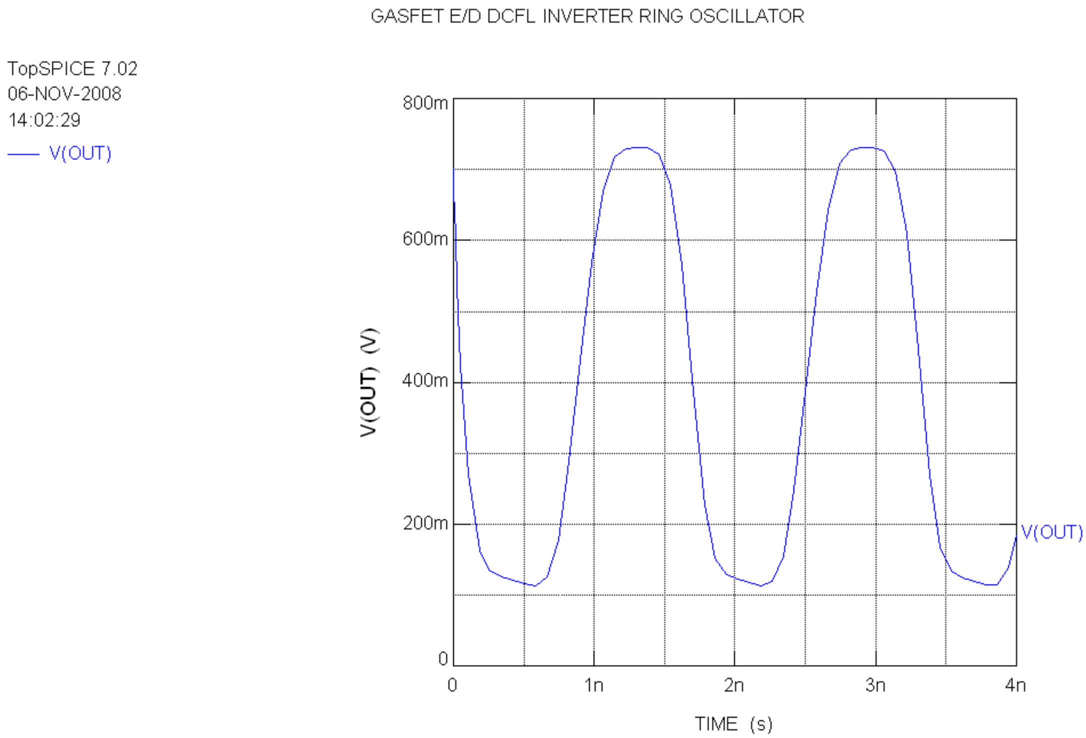

Figure 10: Transient Analysis of Ring Oscillator.

Therefore, if there is the detail circuit of MSP430F2012, CC2500, and seven-segment display, then it is possible to have the appropriate simulation waveforms as desire.

2. Analog Behavioral Modeling

Another way to solve the unknown blocks in TopSpice is to use analog behavioral modeling (ABM), which is including circuit state variables and Laplace transform expressions. Analog behavioral modeling uses arbitrary equation to express, which is equivalent to defining a system of its transfer function. The arbitrary equation can contain constants, circuit variable, arithmetic operators, predefined math function and parameters [4]. There are four advantages of using ABM, first is that no need to modify the simulator for new device implementation. Second, we can use functional block modeling of complex systems and high-level functions. Also, the description of a system or circuit can have several different levels of abstracting during the design process. Finally, a faster simulation of non-critical sections of a circuit will be performed [5]. There are five different methods to process the transfer function, which are POLY, VALUE, TABLE, FREQ, and LAPLACE listed as below.

Method	Way of implementing transfer functions
POLY	Polynomial function of circuit voltages or currents
VALUE	Mathematical equation of circuit variables
TABLE	Look-up table
FREQ	Frequency response table
LAPLACE	New E and G FREQ sources SPARAM table option

Table 1: Methods of Implementing Transfer Functions in TopSpice.

The following Figure 11 has demonstrated VALUE and TABLE in the schematic.

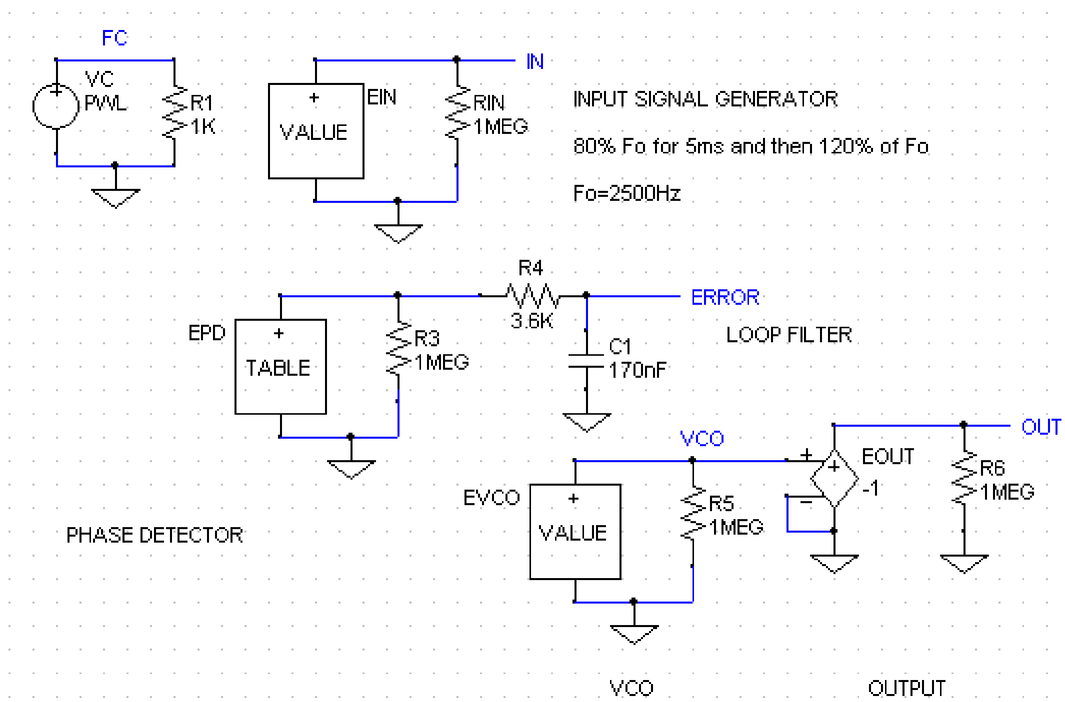

Figure 11: Schematic of Phase Locked Loop

In the schematic, we can see that there are VALUE and TABLE blocks. For the EIN VALUE block, it sets up the parameter value of {SIN(2*PI*FC*TIME*V(FC))}. The EPD TABLE has the parameter values of {V(IN)*V(VCO)} in line one and -1,0.5 1,2 in line two. The EVCO VALUE block has parameter value of

{SIN(2*PI*FC*TIME*V(ERROR))}. Those three blocks have successfully been given values of parameter and have transient analysis response as Figure 12.

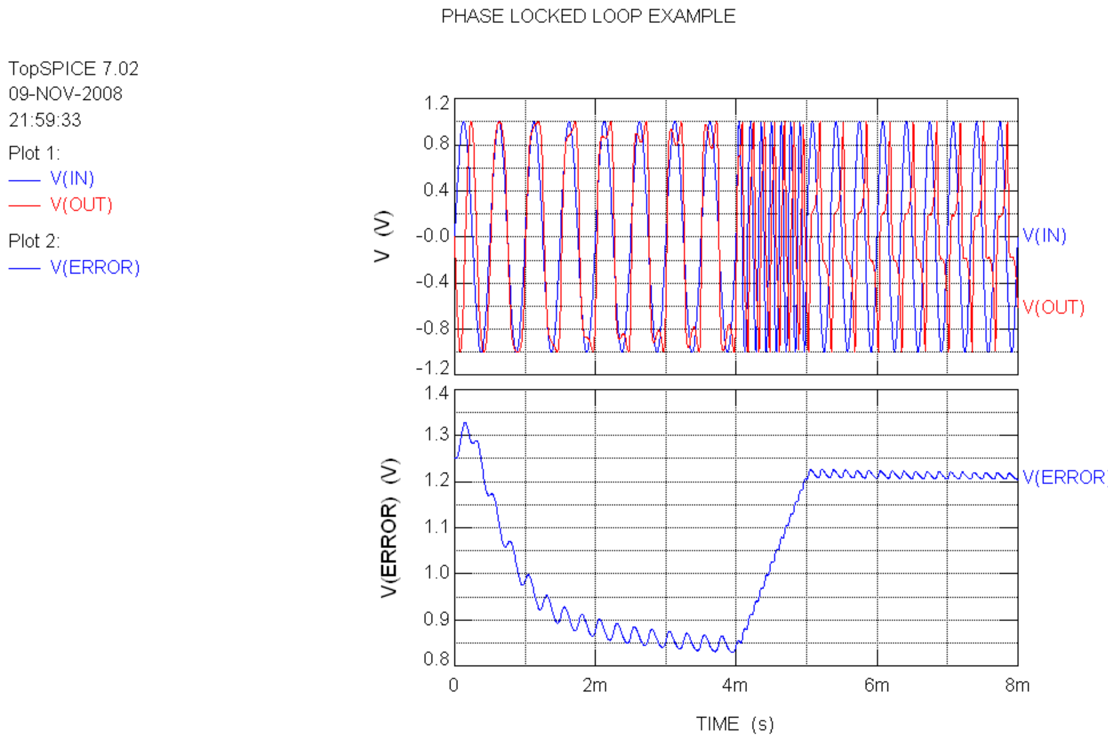

Figure 12: Transient Analysis of Phase Locked Loop

Even though the arbitrary equation can be used in TopSpice, we need to remember that there is convergence problems that might occurred. First of all for circuit state variables, we need to make sure that the functions are well behaved and continuous. Because if we have exponentials and power functions, then it will have high gain block, which result of feedback loop. Second, adding appropriate capacitance will be necessary for delays at input and output nodes. Third, define the functions for all possible values of the circuit variable range. For example, we need to avoid divide by zero error by modifying expression to be {1/(V1)+1u}}. For Laplace transform, we use complex frequency variable "s" in TopSpice.

Conclusion

This project is mainly focusing on the uses for people with hearing disability. By using TopSpice simulation, we can anticipate the problems that might occur in the real circuit. Both microcontroller (MSP430F2012) and RF transceiver (CC2500) have transmitting and receiving parts to communicate with each other in order to intercept and send the signals as the program wanted. Power system includes comparator tells user when the battery is low and voltage regular steps down the voltage to 3.3V in order to use for microcontroller and RF transceiver. Alert system contains vibrator and LED to alert the users. The solution to simulate TopSpice in this project is to use Analog Behavioral Modeling instead of Sub-Circuit. The reason is because the details of most of the components in this project are not released to the public. Therefore, Analog Behavioral Modeling is the best solution. By doing TopSpice simulation on this project, I can understand more not only on circuit behaviors but also on different parts of system behavior on simulation such as microcontroller in order to know more about the whole device rather than practical on one part of device.

Work Citied

[1] S. Murali, L. Benini, and G. De Micheli, “An Application-Specific Design Methodology for On-Chip Crossbar Generation,” *IEEE Trans. Circuit and System*, Vol. 26, pp.1283 – 1296, July 2007.

[2] “High-Speed CMOS Logic 16-Channel Analog Multiplexer/Demultiplexer.” Texas Intruments. 30 Oct. 2007 <2. http://focus.ti.com/lit/ds/symlink/cd74hc4067.pdf>.

[3] “Industrial Analog Current/Voltage.” Texas Intruments. 29 Oct. 2007 <http://focus.ti.com/lit/ds/symlink/xtr300.pdf>.

[4] “Simulator Reference” TopSpice Program. 09 Nov, 2008.

[5] “UserGuide” TopSpice Program. 09 Nov, 2008.